Project Report

Suwannee River Water Managment LiDAR

Prepared For:

United States Geological Survey

Prepared By:

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CONTRACT: #G10PC00093
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TASK ORDER: #G12PD00242

Project Report
LiDAR Collection, Processing, and QA/QC

2012 Suwannee Managment LiDAR Task Order

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1 Introduction and Specifications

Digital Aerial Solutions, LLC (DAS) was tasked to collect and process a Light Detection And Ranging (LiDAR) derived elevation dataset for the Suwannee Managment, FL. The Suwannee Managment survey area encompasses approximately 725 square miles. Aerial LiDAR data was collected utilizing an ALS60. The ALS60 is a discrete return topographic LiDAR mapping system manufactured by Leica Geosystems. LiDAR data collected for the Suwannee Managment survey has a nominal pulse spacing of 0.9 meters, and includes up to 4 discrete returns per pulse, along with intensity values for each return.

LiDAR datasets were post processed to generate elevation point cloud swaths for each flight line. Deliverables include the point cloud swaths, tiled point clouds classified by land cover type, breaklines to support hydro-flattening of digital elevation models (DEM)s, and bare-earth DEM tiles. Point cloud deliverables are stored in the LAS version 1.2 format, point data record format 1. The tiling scheme for tiled deliverables is a 5000 Feet x 5000 Feet grid aligned and named according Florida State plane North index. All deliverables were generated in conformance with the *U.S. Geological Survey National Geospatial Program Guidelines and Base Specifications, Version 13 - ILMF 2010.*

2 Spatial Reference System

The spatial reference of the data is as follows.

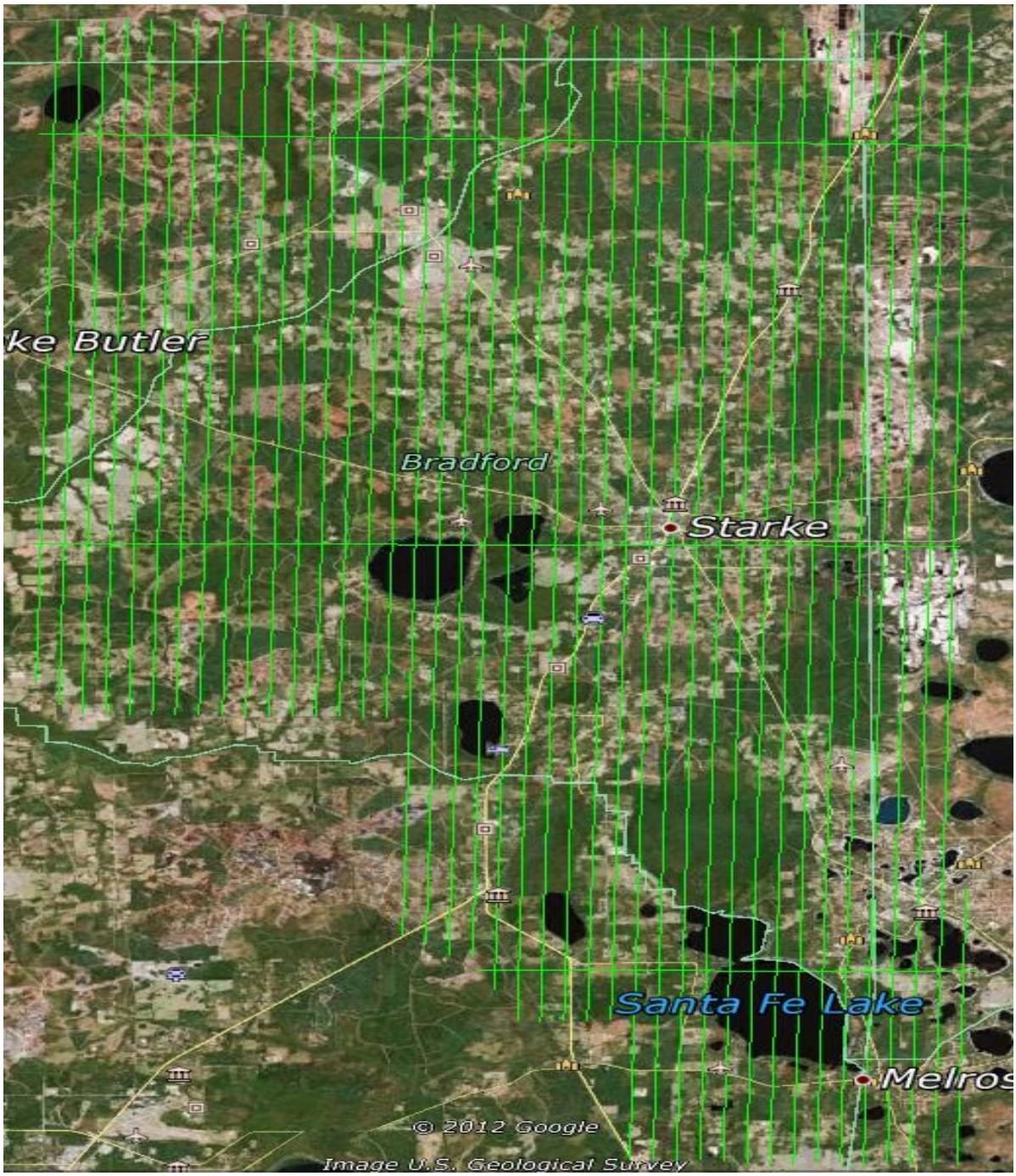
Horizontal Spatial Reference
- Datum: North American Datum of 1983/ 2007 HARN
- Coordinates: Florida State Plane North

Vertical Spatial Reference
All datasets are available with orthometric elevation; point cloud datasets are also available with ellipsoid heights
- Datum: North American Vertical Datum of 1988 (GEOID09)

3 LiDAR Acquisition

3.1 Survey Area

The Suwannee Managment survey area covers approximately 725 square miles in the Bradford County located in north central Florida. The flight plan consisted of 40 survey lines and 3 control lines.



3.2 Acquisition Parameters

Acquisition parameters include the sensor configuration and the flight plan characteristics, and are selected based on a number of project specific criteria. Criteria reviewed include the required accuracies for the final dataset, the land cover types within the project survey area, and the required nominal pulse spacing. Acquisition parameters selected for the Suwannee River water Management LiDAR project are summarized below.

Parameter	Value
Flying Height Above Ground Level	3,775 feet
Nominal Sidelap	30%
Nominal Speed Over Ground	130 knots
Field of View	30°
Laser Rate	200 kHz
Scan Rate	68.4 hz
Maximum Cross Track Spacing	0.98 meters
Maximum Along Track Spacing	0.98 meters
Average Spacing	1 meters

3.3 Acquisition Mission

The acquisition mission for the Suwannee Managment LiDAR survey was coordinated to be acquired in 1 week. Collection began on March 27th 2012 and was completed on March 29th, 2012, A complete flight log for the acquisition mission may be found in Appendix B.

3.4 Airborne GPS/IMU

Airborne global positioning system (GPS) and inertial measurement unit (IMU) data was collected on the aircraft during the acquisition mission, providing sensor position and orientation information for geo-referencing the LiDAR data. Airborne GPS observations were collected at a frequency of 2Hz, and IMU observations are collected at a frequency of 200Hz.

Aircraft	Sensor	GPS Lever Arm (m)	IMU Lever Arm (m)
C421 – N112MJ	ALS60 – SN6130	x: -0.210, y: -0.060, z: -1.370	x: -0.450, y: -0.159, z: -0.169

In addition, GPS data was collected with ground base stations during the acquisition mission, providing corrections to support differential post-processing of the airborne GPS. One ground base station was setup at an NGS Benchmark (Keyport) as the base of operation. The additional ground base station were selected and place threw the project to ensure complete coverage. Ground GPS observations were collected at a frequency of 2Hz.

4 LiDAR Processing

4.1 Acquisition Post-Processing

Once the acquisition was completed, initial post-processing was performed to generate geo-referenced LiDAR elevation point clouds.

The airborne GPS dataset was differentially corrected using the ground base station GPS datasets collected by DAS and USGS in Waypoint's GrafNav software. Grafnav computes the GPS dataset corrections in both forward and reverse chronological sequence, obtaining two solutions for the GPS trajectory. The differences between these two solutions were reviewed to ensure a consistent result, and agree within +/- 3cm. The forward and reverse solutions also show good fit between the two different base stations used in the post-processing.

Differentially corrected airborne GPS data was merged with the airborne IMU dataset in Leica's IPAS software through Kalman filtering techniques. IPAS applies the reference lever arms for the GPS and IMU measurement systems during processing to determine the trajectory (position and orientation) of the LiDAR sensor during the acquisition mission. Estimated lever arm values reported posteriori validate the measurements made during sensor installation in the aircraft.

Raw LiDAR sensor ranging data and the final sensor trajectory from IPAS were processed in Leica's ALSPP software to produce the LiDAR elevation point cloud swaths for each flightline, stored in LAS version 1.2 file format. Quality control of the swath point clouds was performed to validate proper function of the sensor systems, full coverage of the project AOI, and point density consistent with the planned nominal pulse spacing. The LiDAR data collected for the Suwannee Managment survey area passed these quality control checks.

Swath point clouds were assigned a unique File Source ID within the LAS file format before further processing. Swath files for the Suwannee Managment LiDAR project were numbered beginning with 1 in chronological order of acquisition. Shapefiles representing the geographic extent of the raw point cloud data were produced using the SIS LiDAR Testing Extension (LTE).

4.2 Geometric Calibration

Geometric and positional accuracy of the LiDAR swath point clouds is highly dependent on accurate calibration of the various subsystems within the LiDAR sensor system. Sensor calibration parameters fall into two categories, one being those parameters proprietary to the manufacturer's sensor design, and the other being parameters common to most commercial airborne LiDAR sensors, the IMU to laser reference system alignment angles (bore-site), and mirror deformation constants (scaling).

The manufacturer specific calibration parameters are applied in Leica's ALSPP software for the ALS60 sensor system. Terrasolid's Terramatch software was used to calculate the IMU bore-site and mirror scale parameters for the Suwannee Managment's LiDAR data. Within the TerraMatch software, the Tie-line workflow was used to solve for the parameters. The Tie-line workflow involves automated selection of numerous 'tie-lines', which represent a linear segment fit to the data that should have the same slope, azimuth, position and elevation, within the overlap sections of the survey lines and control lines. The tie-lines provide observations for algorithms within TerraMatch to solve for the bore-site and mirror scale parameters for the lift.

The Tie-line workflow is dependent upon well distributed tie-lines throughout the swath point clouds to effectively solve for bore-site and mirror scale parameters with the automated algorithms. The Suwannee Managment survey area did not support this requirement, due to the large water area within the

survey and control lines. Manual estimation of the bore-site and mirror scale parameters was performed using the observed tie-lines in overlap areas.

The final step of geometric calibration is to determine elevation (z) offset corrections to be applied to the swath point clouds. Z values calculated during the course of the acquisition mission can vary at the centimeter level as the GPS satellite constellation observed in the survey area changes with satellites moving through their orbits over the course of the mission. Baseline length from the ground base station GPS to the airborne GPS can also impact the z values calculated for the swath point clouds. Z offset corrections are calculated in two steps; a relative step, where individual lines are corrected one to another using the adjusted tie-lines from the bore-site and mirror scale calculation step; and an absolute step, where groups of lines are leveled to project ground control.

For the Suwannee Managment LiDAR project, the control lines were used to determine relative z offset corrections in areas of discernible ground. The base station operated by DAS in the survey area provided for minimal baseline lengths, resulting in generally good z agreement between the survey lines and control lines.

The final geometrically calibrated swath point clouds were compared to the bare-earth profile survey data. The data fit the profile surveys within the vertical accuracy tolerance specified for the project. Full documentation of the vertical accuracy checks maybe found in section 5.1.

4.3 Point Cloud Classification

Georeference information was applied to the swath point could LAS files. Geometrically calibrated swath point clouds were cut into 5000 feet x 5000 feet Florida State Plane North format tiles for point cloud classification and derived product creation. It is important to note that US National Grid tiles are non-orthogonal when stored and displayed in a geographic coordinate system. As a result, tiled vector data does not have overlap, but tiled raster data does have overlap to permit seamless display of the data products.

Tiled point cloud data was processed in Terrasolid's Terrascan software to assign initial classification values. The Terrascan software provides a number of routines to algorithmically detect and assign points to their appropriate class. Points left unclassified by the algorithmic routine remain as Class 1 – Processed, but unclassified. Automated classification routines assigned points to one of the following classes:

- Class 1 – Processed, but unclassified
- Class 2 – Bare-earth ground
- Class 7 – Noise
- Class 9 – Water
- Class 10 – Ignored Ground
- Class 11 – Withheld

Automated classification results were reviewed for each tiled point cloud, and manual edits made where necessary to correct for misclassified points. Points remaining in Class 1 after the automated classification routines were run were left in Class 1. Points falling outside of a 105 meter buffer of the project AOI polygon were excluded from the tiled point clouds.

4.4 Breakline Collection

Manual breakline collection was performed to support the hydro-flattening requirements of the project's DEM deliverables. Breaklines were collected directly from the classified point clouds and from triangulated irregular network (TIN) surface models built from the classified point clouds, in Terrasolids's Terrascan and Terramodeler software. Breakline features were collected as design file elements in Bentley's Microstation software. Breaklines were converted to ESRI 3D shapefile format for the breakline deliverable, and tiled to the project US National Grid index.

The data collected for the Suwannee Managment LiDAR survey maintained significant point density in the water, marsh, and swamp, limiting the usefulness of point density as guiding factor in breakline placement.

Points classified as Class 2 – Bare-earth ground, falling within a one meter buffer of the collected breaklines, were reassigned to Class 10 – Ignored Ground. These points are excluded from the surface model during DEM generation to preserve the hydro-flattening characteristics of the breaklines.

4.5 DEM Generation

The final classified point clouds and collected breaklines were reviewed for completeness and conformance to the task order scope of work and the NGP version 13 guidelines. Within the Terramodeler software, points in Class 2 – Bare-earth ground and the breaklines were combined to generate TIN elevation models for each tile, from which the bare-earth DEM tiles were interpolated and exported as 32 bit float Arc Grid.

5 Quality Control

5.1 Point Clouds

Accuracy and completeness of the LiDAR point clouds directly impacts the quality of all other derived LiDAR derived products. Ensuring a quality LiDAR dataset begins with proper mission planning and execution. Ground GPS base stations are located such that GPS baselines between the ground and airborne receivers do not exceed 30km. For the Suwannee Management LiDAR project, two base stations were run to meet this requirement, one at the field operations airport and one within the survey area. Static alignment is performed both before take-off and after landing to allow for GPS integer ambiguity resolution. Sensor operators carefully monitor the LiDAR unit and its various subsystems during the acquisition mission to ensure proper function. Airborne GPS positional dilution of precision (PDOP) estimates are monitored to ensure they remain less than 3.The optical system is monitored to ensure there are no ranging errors encountered during the flight lines.

During acquisition post-processing estimates of the trajectory data accuracy are reviewed to ensure they will support the required accuracies of the point cloud data. The trajectory accuracy is a function of the differentially corrected GPS data and the IMU data.

The raw swath point clouds generated from ALSPP are reviewed as another check for proper sensor function. The point clouds are reviewed for full coverage of the AOI, required point density and nominal pulse spacing, clustering, proper intensity values, full swath coverage within the planned field of view, and planned survey line overlap.

Geometric calibration quality control validates that the positional accuracy requirements of the project are met, and includes relative accuracy assessments for intra-swath (within) and inter-swath (between) accuracy, along with absolute accuracy assessments against project ground control.

Relative vertical accuracy assessments are normally made using the tie-lines generated in the Terramatch software, as these lines provide positional observations throughout the extent of individual swaths, and between neighboring swaths.

Horizontal accuracy assessments of LiDAR data require the presence of vertical targets such as buildings within in the survey area. Field check points are surveyed at the corners of the building roofs, and the surveyed locations compared to the estimated corner locations in the LiDAR point cloud. The Suwannee Management survey area did not present any accessible buildings for use as vertical targets. From the manufacturer's specifications, the estimated horizontal accuracy at one sigma, based on flying height for the project, is between 10cm and 20cm.

Absolute vertical accuracy assessments for the point cloud data are made against ground check point data. For the Suwannee Management survey, ground check point data consisted of the ground GPS base station, and real-time kinematic (RTK) GPS techniques.

150 feet x 150 feet. Check point locations were collected at 1 – second intervals during the RTK survey. Points collected during the static pre-initialization and post-initialization were removed from the assessment so as not to bias the assessment.

Local TIN models of the elevation points are built around each ground check points. The tin model elevation is sampled at the horizontal position of the ground check point. The TIN model elevation and ground check point survey elevation values were used to calculate the fundamental vertical accuracy (FVA) of the swath point clouds as described in Section 1.5 of the NDEP Elevation Guidelines Version 1. The FVA of the TIN tested RMSEz 0.19 feet and 0.38 feet at the 95% confidence level in open terrain. FVA of the DEM tested at an RMSEz of 0.19 feet and 0.37 feet at the 95% confidence level in open terrain. The full calculations for all check points can be found in Appendix D.

FVA of TIN

$RMSE_Z$ =	0.19	feet
NSSDA=	0.38	feet

FVA of DEM

$RMSE_Z$ =	0.19	feet
NSSDA=	0.37	feet

The tiled point cloud products were reviewed for full coverage of the AOI and proper classification. As part of the QC process, TINs are built in the Terramodeler software for each tile using the ground class and the hydro-flattening breaklines. The TINs are reviewed for non-ground features, and edited where necessary to remove any remaining non-ground features. Points were also reviewed for absolute elevation, and points falling below the selected orthometric elevation for water were removed from the ground class.

5.2 Breaklines

The final breaklines in ESRI 3D shapefile format were reviewed for topological consistency and correct elevation. Breaklines features are continuous and do not have overlaps or dangles.

5.3 Digital Elevation Models

Digital elevation models (DEMs) were reviewed for conformance with the SOW and the NGP version 13 guidelines. DEM files were loaded in the Global Mapper software and inspected visually for edge matching between tiles, void areas within the project AOI, and proper coding of the NODATA values. DEM file naming was verified for consistency with the US National Grid tile index.

Appendix A. Flight Logs

ALS60 LiDAR Flight Log

Project	Suwannee 2012	ALS60	N6130						Sensor Operator/s
						-			Bertin Evina-Ze
Date/Julian:	3/27/2012	Mem Drive MM60	Int. Time:	TAR AIRSPD (KNTS)			Base PID:		Pilot/s
Hobbs End	600.3	1-600049630		140			AR1849		MWAZ
Hobbs ST	595.7	LIFT A		TAR ALT AGL (ft):		Flight Plan(s):	Base Height:	Aircraft	Airport Idnt:
Flight Time	4.6			5,550		Plant City CAL	1.724	421C 112MJ	K42J

Lift		Flight Line	Mission Line	UTC time: B:	UTC time: E:	GPS Altitude: ASL:	Direction	Speed: kts:	Memory	S/Vs:	Position Acc. PDOP	Position Acc. HDOP	Comments and Conditions:
						-	-	-	148				Static Alignment
A		101	120327_164521	16:45	16:52	5,560	0	136	146	17	1.2	0.6	CLEAR
		102	120327_165627	16:56	17:04		180	131	144	18	1.1	0.6	CLEAR
		103	120327_170732	17:07	17:15		0	130	142	19	1.1	0.6	CLEAR
		104	120327_171827	17:18	17:26		180	129	140	18	1.1	0.6	CLEAR
		105	120327_172942	17:29	17:37		0	137	138	18	1.1	0.6	CLEAR
		103	120327_181115	18:11	18:19		180	124	135	15	1.2	0.7	CLEAR
		106	120327_182217	18:22	18:30		0	131	132	15	1.2	0.7	CLEAR
		107	120327_183337	18:33	18:48		180	125	130	15	1.1	0.7	ABORT
		112	120327_185114	18:51	18:59		0	144	129	15	1.1	0.7	CLEAR
		111	120327_190213	19:02	19:10		180	130	127	16	1.1	0.7	CLEAR
		110	120327_191349	19:13	19:21		0	147	125	16	1.1	0.7	CLEAR
		109	120327_192712	19:27	19:35		180	131	123	16	1.1	0.7	CLEAR
		108	120327_193823	19:33	19:46		0	139	121	16	1.1	0.7	CLEAR
		107	120327_194926	19:49	19:57		180	142	119	16	1.1	0.7	CLEAR
		113	120327_200012	20:00	20:08		0	136	117	17	1.1	0.6	CLEAR
		114	120327_201131	20:11	20:19		180	125	115	16	1.2	0.7	CLEAR
		115	120327_202219	2,022	20:30		0	138	113	16	1.2	0.7	CLEAR
		116	120327_203322	20:33	21:41		180	134	111	16	1.3	0.7	CLEAR
		143	120327_204545	20:46	20:48		270	140	110	17	1.1	0.6	Cross Strip(partial)
		144	120327_205607	20:56	20:58		90	134	109	16	1.2	0.7	Cross Strip(partial)

ALS60 LiDAR Flight Log

Project	Suwannee 2012	ALS60	N6130						Sensor Operator/s
						-			Bertin Evina-Ze
Date/Julian:	3/27/2012	Mem Drive MM60	Int. Time:	TAR AIRSPD (KNTS)			Base PID:		Pilot/s
Hobbs End	603.4	1-600049630		140			AR1849		MWAZ
Hobbs ST	600.8	LIFT B		TAR ALT AGL (ft):		Flight Plan(s):	Base Height:	Aircraft	Airport Idnt:
Flight Time	2.6			5,550		Plant City CAL	1.724	421C 112MJ	K42J

Lift		Flight Line	Mission Line	UTC time: B:	UTC time: E:	GPS Altitude: ASL:	Direction	Speed: kts:	Memory	S/Vs:	Position Acc. PDOP	Position Acc. HDOP	Comments and Conditions:
						-	-	-	109				Static Alignment
B		141	120327_225953	23:00	23:03	5,560	0	137	108	20	1.1	0.6	CLEAR
		140	120327_231017	23:10	23:22		0	139	105	19	1.2	0.6	CLEAR
		139	120327_232551	23:25	23:38		180	132	102	18	1.4	0.6	CLEAR
		138	120327_234147	23:41	23:54		0	141	98	18	1.3	0.6	CLEAR (scattered small clouds last 7KM)
		122	120327_235837	23:58	12:10		180	130	96	21	1.1	0.6	CLEAR
		121	120328_001307	24:13	24:23		0	140	93	21	1.1	0.6	CLEAR
		120	120328_002654	24:27	24:37		180	135	90	21	1.0	0.5	CLEAR
		119	120328_004043	24:40	24:50		0	138	88	19	1.1	0.6	ABORT
		118	120328_005340	24:53	1:04		180	134	85	19	1.0	1.0	CLEAR
		117	120328_010725	1:07	1:18		0	141	82	18	1.0	0.6	CLEAR
		144	120328_012200	1:22	1:27		91	134	81	18	1.0	0.6	Cross Strip(partial)
		143	120328_013203	1:32	1:57		270	143	80	17	1.1	0.6	Cross Strip(partial)
		142	120328_014345	1:43	1:47		90	137	79	17	1.1	0.6	Cross Strip

ALS60 LiDAR Flight Log

Project	Suwannee 2012		ALS60	N6130						Sensor Operator/s
							-			Bertin Evina-Ze
Date/Julian:	3/29/2012		Mem Drive MM60	Int. Time:	TAR AIRSPD (KNTS)			Base PID:		Pilot/s
Hobbs End	606.0		6-600110120		140			AR1849		MWAZ
Hobbs ST	603.4		LIFT A		TAR ALT AGL (ft):		Flight Plan(s):	Base Height:	Aircraft	Airport Idnt:
Flight Time	2.6				5,550		Plant City CAL	1.724	421C 112MJ	K42J

Lift		Flight Line	Mission Line	UTC time: B:	UTC time: E:	GPS Altitude: ASL:	Direction	Speed: kts:	Memory	S/Vs:	Position Acc. PDOP	Position Acc. HDOP	Comments and Conditions:
						-	-	-	136				Static Alignment
A		137	120329_141549	14:15	14:28	5,560	0	139	132	16	1.5	0.7	CLEAR
		138	120329_143140	14:31	14:35		181.2	140	132	19	1.1	0.6	CLEAR(partial 10 km from North)
		136	120329_144255	14:43	14:55		181.2	142	128	19	1.1	0.6	CLEAR
		135	120329_145847	14:58	15:11		01.2	140	125	19	1.1	0.6	CLEAR
		134	120329_151413	15:14	15:26		181.2	142	122	19	1.0	0.6	CLEAR
		133	120329_152939	15:29	15:42		01.2	141	119	18	1.4	0.6	CLEAR
		132	120329_154511	15:45	15:57		181.2	140	116	19	1.3	0.7	CLEAR
		123	120329_160119	16:01	18:12		01.2	144	113	18	1.4	0.6	CLEAR
		144	120329_161543	16:15	16:20		91.1	140	112	18	1.3	0.6	CLEAR (Cross Strip)
		143	120329_162536	16:25	16:30		270.3	138	111	19	1.1	0.6	CLEAR (Cross Strip)

ALS60 LiDAR Flight Log

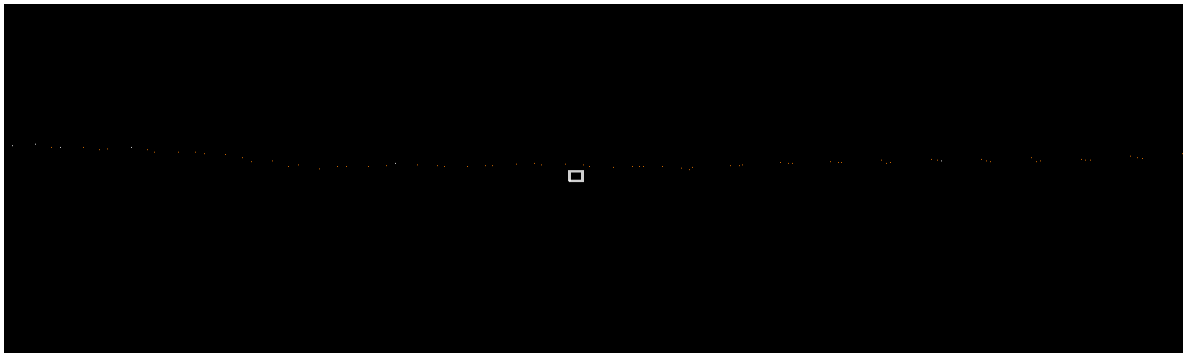
Project	Suwannee 2012		ALS60	N6130						Sensor Operator/s
							-			Bertin Evina-Ze
Date/Julian:	3/29/2012		Mem Drive MM60	Int. Time:	TAR AIRSPD (KNTS)			Base PID:		Pilot/s
Hobbs End	609.2		6-600110120		140			AR1849		MWAZ
Hobbs ST	606.0		LIFT B		TAR ALT AGL (ft):		Flight Plan(s):	Base Height:	Aircraft	Airport Idnt:
Flight Time	3.2				5,550		Plant City CAL	1.724	421C 112MJ	K42J

Lift		Flight Line	Mission Line	UTC time: B:	UTC time: E:	GPS Altitude: ASL:	Direction	Speed: kts:	Memory	S/Vs:	Position Acc. PDOP	Position Acc. HDOP	Comments and Conditions:
						-	-	-	111				Static Alignment
B		124	120330_030536	3:05	3:16	5,560	01.2	140	108	19	1.1	0.7	CLEAR
		125	120330_031956	3:19	3:31		181.2	128	105	15	1.4	0.8	CLEAR
		126	120330_033356	3:33	3:44		01.2	142	103	15	1.3	0.7	CLEAR
		127	120330_034836	3:48	4:01		01.2	138	100	16	1.1	0.7	CLEAR
		128	120330_040441	4:04	4:17		181.2	143	97	15	1.2	0.7	CLEAR
		129	120330_042041	4:20	4:33		01.2	133	93	15	1.2	0.7	CLEAR
		130	120330_043615	4:36	4:48		01.2	139	90	16	1.2	0.7	CLEAR
		131	120330_045142	4:51	5:04		181.2	140	87	16	1.2	0.7	CLEAR(partial 20km)
		132	120330_050658	5:06	5:12		01.2	137	86	18	1.1	0.7	CLEAR
		142	120330_051809	5:18	5:21		270.5	137	85	18	1.1	0.7	CLEAR (Cross Strip)
		143	120330_052900	5:29	5:35		90.2	142	83	18	1.1	0.7	CLEAR (Cross Strip)
		144	120330_054127	5:41	5:48		271.2	135	81	18	1.1	0.7	CLEAR (Cross Strip)

Appendix B. Vertical Accuracy Calculations

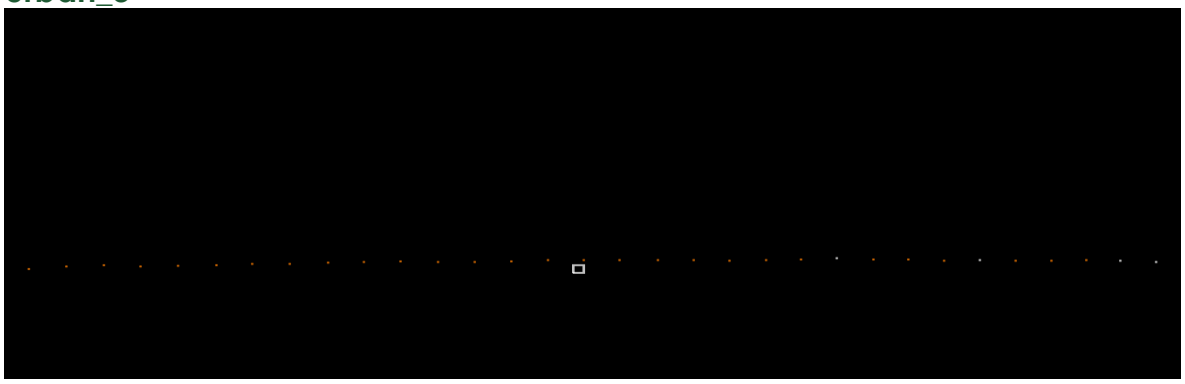
Check point outliers identified through Terra Solid software were tagged for further investigation. Spatial analysis and analyzed mean of the outliers were performed prior to elimination from the set of observations. These errors were not caused by misinterpretations of terrain surface and could not be corrected through standardized adjustment. Eliminated observations are as followed:

FVA-126



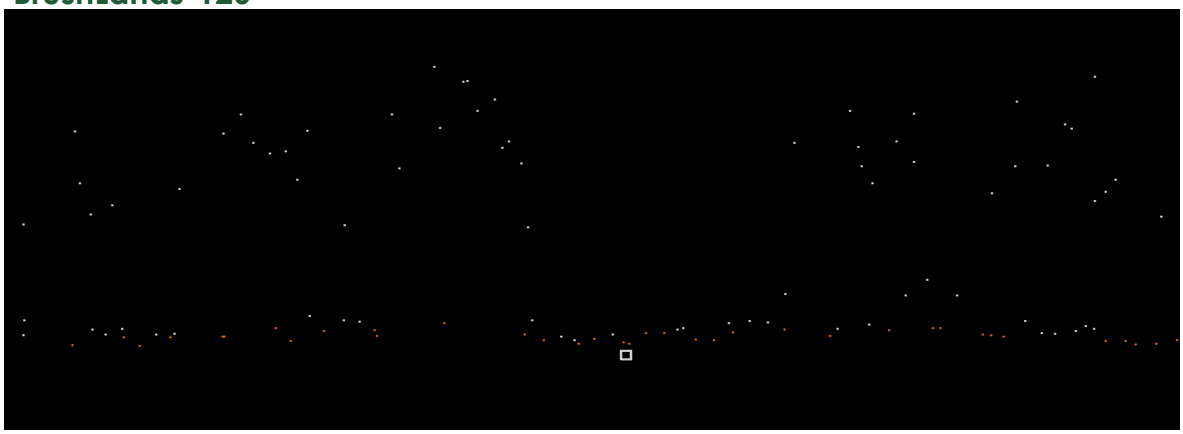
FVA_GCT_FL03

Urban_3



Tall_Weeds-126

BrushLands-126



BrushLands-128

BrushLands-129

Brush_5

Forested-126

Forested_7

DEM FVA Report

LandCover Type: BareEarth
Minimum DZ: -0.354
Maximum DZ: 0.075
Mean DZ: -0.12
Mean Magnitude DZ: 0.72
Number Observations: 13
Standard Deviation DZ: 0.15
RMSE Z: 0.193
95% Confidence Level Z: 0.377
Units: Feet

LAS FVA TIN Report

Number	Easting	Northing	Known Z	Laser Z	Dz
FVA-120	376023.608	3336044.956	43.489	43.492	+0.003
FVA-121	388407.351	3329031.879	41.876	41.870	-0.006
FVA-122	399334.651	3332613.032	62.170	62.046	-0.124
FVA-123	394830.753	3320114.523	49.081	48.970	-0.111
FVA-124	378073.099	3325033.311	44.841	44.870	+0.029
FVA-125	386446.937	3317618.932	45.081	45.090	+0.009
FVA-127	386649.858	3306967.472	45.340	45.350	+0.010
FVA-128	395923.822	3312455.734	50.686	50.650	-0.036
FVA-129	387115.982	3296706.848	45.413	45.380	-0.033
FVA-130	397122.184	3287175.550	45.186	45.110	-0.076
FVA_A039	398157.807	3287076.463	48.615	48.600	-0.015
FVA_GCT-FL01	401618.130	3335741.402	31.498	31.440	-0.058
FVA_Keyport	398953.763	3301556.874	55.576	55.520	-0.056

Average dz -0.134
Minimum dz -0.406
Maximum dz +0.095
Average magnitude 0.711
Root mean square 0.196
Std deviation 0.157

DEM Urban SVA Report

LandCover Type: Urban
Minimum DZ: -0.413
Maximum DZ: 0.416
Mean DZ: -0.029
Mean Magnitude DZ: 0.925
Number Observations: 8
Standard Deviation DZ: 0.311
RMSE Z: 0.29
95th Percentile: 0.416
Units: Feet

LAS Urban SVA TIN Report

Number	Easting	Northing	Known Z	Laser Z	Dz
UrbAN_1	379589.117	3329621.049	44.122	44.230	+0.108
UrbAN_2	387557.815	3323784.328	41.150	41.260	+0.110
UrbAN_4	392197.105	3314096.007	48.682	48.630	-0.052
UrbAN_5	378012.722	3315245.013	44.040	43.920	-0.120
UrbAN_6	394872.446	3308376.255	51.670	51.630	-0.040
UrbAN_7	397274.798	3297366.348	47.735	47.620	-0.115
UrbAN_8	376418.415	3321555.141	40.123	40.150	+0.027
UrbAN_9	398592.730	3287008.157	47.995	47.960	-0.035

Average dz -0.095
Minimum dz -0.387
Maximum dz +0.360
Average magnitude 0.223
Root mean square 0.278
Std deviation 0.259

DEM Tallweeds SVA Report
LandCover Type: Tall weeds
Minimum DZ: -0.173
Maximum DZ: 0.446
Mean DZ: 0.15
Mean Magnitude DZ: 0.81
Number Observations: 14
Standard Deviation DZ: 0.200
RMSE Z: 0.24
95th Percentile: 0.446
Units: Feet

LAS Tall Weeds SVA TIN Report

Number	Easting	Northing	Known Z	Laser Z	Dz
Tall_weeds-120	376441.570	3334475.969	41.579	41.560	-0.019
Tall_weeds-121	388254.828	3329078.970	40.855	41.020	+0.165
Tall_weeds-122	398604.720	3330802.474	59.667	59.750	+0.083
Tall_weeds-123	395386.078	3321695.609	47.499	47.500	+0.001
Tall_weeds-124	376035.358	3320812.099	41.475	41.470	-0.005
Tall_weeds-125	386369.376	3317729.037	44.484	44.590	+0.106
Tall_weeds-127	387718.375	3308621.080	42.711	42.710	-0.001
Tall_weeds-128	396736.171	3311658.297	52.138	52.230	+0.092
Tall_weeds-129	386097.411	3295104.073	45.744	45.920	+0.176
Tall_weeds-130	394616.788	3287754.413	48.023	47.940	-0.083
TALL_WEEDS_2	387206.038	3324317.000	39.204	39.270	+0.066
TALL-WEEDS_5	383304.871	3313603.911	45.119	45.190	+0.071
TALL_WEED_6	395138.015	3307597.177	51.076	51.120	+0.044
TALL_WEED_7	396941.594	3299291.706	52.651	52.610	-0.041

Average dz +0.21
Minimum dz -0.26
Maximum dz +0.57
Average magnitude 0.27
Root mean square 0.28
Std deviation 0.24

DEM Brushland SVA Report
LandCover Type: Brushland
Minimum DZ: -0.465
Maximum DZ: 0.597
Mean DZ: 0.016
Mean Magnitude DZ: 0.895
Number Observations: 12
Standard Deviation DZ: 0.308
RMSE Z: 0.298
95th Percentile: 0.597
Units: Feet

LAS BrushLand SVA TIN Report

Number	Easting	Northing	Known Z	Laser Z	Dz
BrushLands-120	379573.103	3329480.977	43.285	43.420	+0.135
BrushLands-121	388380.199	3328368.774	40.993	40.990	-0.003
BrushLands-122	398242.497	3333062.287	59.967	59.936	-0.031
BrushLands-123	394358.546	3318530.908	47.109	47.010	-0.099
BrushLands-124	376050.027	3320729.823	41.180	41.159	-0.021
BrushLands-125	386040.423	3319056.504	41.632	41.670	+0.038
BrushLands-127	385849.609	3306282.951	44.329	44.360	+0.031
BrushLands-130	399008.722	3287675.998	48.842	48.700	-0.142
BRUSH_2	387610.023	3323840.154	40.297	40.440	+0.143
BRUSH_6	395701.467	3305921.284	52.643	52.720	+0.077
BRUSH_6B	395722.018	3305926.747	52.795	52.710	-0.085
BRUSH_7	396944.828	3299341.982	52.607	52.709	+0.102

Average dz +0.137
Minimum dz -0.50
Maximum dz +0.459
Average magnitude 0.843
Root mean square 0.269
Std deviation 0.278

DEM Forested SVA Report

LandCover Type: Forested
Minimum DZ: -0.383
Maximum DZ: 0.57
Mean DZ: 0.078
Mean Magnitude DZ: 0.748
Number Observations: 13
Standard Deviation DZ: 0.229
RMSE Z: 0.232
95th Percentile: 0.57
Units: Feet

LAS Forested SVA TIN Report

Number	Easting	Northing	Known Z	Laser Z	Dz
Forested-120	375996.300	3336087.374	43.116	43.160	+0.044
Forested-121	388492.953	3328995.119	42.022	42.020	-0.002
Forested-122	399235.218	3332621.006	62.386	62.280	-0.106
Forested-123	394787.302	3320128.478	48.448	48.460	+0.012
Forested-124	377923.648	3324991.265	44.666	44.850	+0.184
Forested-125	386689.172	3317600.259	42.462	42.560	+0.098
Forested-127	386692.039	3306856.792	44.787	44.860	+0.073
Forested-128	395923.985	3312508.638	49.881	49.941	+0.057
Forested-129	387067.235	3296645.427	45.857	45.868	+0.002
Forested-130	397030.185	3287298.871	44.439	44.540	+0.101
FOREST_2	388113.522	3323918.830	40.398	40.390	-0.008
FOREST_5	379457.452	3313578.590	47.133	47.130	-0.003
FOREST_6	395039.187	3307357.845	50.440	50.350	-0.090

Average dz	+0.216
Minimum dz	-0.347
Maximum dz	+0.603
Average magnitude	0.8
Root mean square	0.259
Std deviation	0.255

DEM CVA Report

LandCover Type: ALL
Minimum DZ: -0.465
Maximum DZ: 0.597
Mean DZ: 0.029
Mean Magnitude DZ: 0.826
Number Observations: 60
Standard Deviation DZ: 0.26
RMSE Z: 0.22
95th Percentile: 0.469
Units: Feet

LAS CVA TIN Report

Number	Easting	Northing	Known Z	Laser Z	Dz
FVA-120	376023.608	3336044.956	43.489	43.420	-0.069
FVA-121	388407.351	3329031.879	41.876	41.870	-0.006
FVA-122	399334.651	3332613.032	62.170	62.050	-0.120
FVA-123	394830.753	3320114.523	49.081	48.970	-0.111
FVA-124	378073.099	3325033.311	44.841	44.870	+0.029
FVA-125	386446.937	3317618.932	45.081	45.090	+0.009
FVA-127	386649.858	3306967.472	45.340	45.350	+0.010
FVA-128	395923.822	3312455.734	50.686	50.650	-0.036
FVA-129	387115.982	3296706.848	45.413	45.380	-0.033
FVA-130	397122.184	3287175.550	45.186	45.110	-0.076
FVA_A039	398157.807	3287076.463	48.615	48.600	-0.015
FVA_GCT-FL01	401618.130	3335741.402	31.498	31.440	-0.058
FVA_Keyport	398953.763	3301556.874	55.576	55.520	-0.056
UrbAN_1	379589.117	3329621.049	44.122	44.230	+0.108
UrbAN_2	387557.815	3323784.328	41.150	41.260	+0.110
UrbAN_4	392197.105	3314096.007	48.682	48.630	-0.052
UrbAN_5	378012.722	3315245.013	44.040	43.920	-0.120
UrbAN_6	394872.446	3308376.255	51.670	51.630	-0.040
UrbAN_7	397274.798	3297366.348	47.735	47.620	-0.115
UrbAN_8	376418.415	3321555.141	40.123	40.150	+0.027
UrbAN_9	398592.730	3287008.157	47.995	47.960	-0.035
Tall_weeds-120	376441.570	3334475.969	41.579	41.560	-0.019
Tall_weeds-121	388254.828	3329078.970	40.855	41.020	+0.165
Tall_weeds-122	398604.720	3330802.474	59.667	59.750	+0.083
Tall_weeds-123	395386.078	3321695.609	47.499	47.500	+0.001
Tall_weeds-124	376035.358	3320812.099	41.475	41.470	-0.005
Tall_weeds-125	386369.376	3317729.037	44.484	44.590	+0.106
Tall_weeds-127	387718.375	3308621.080	42.711	42.710	-0.001
Tall_weeds-128	396736.171	3311658.297	52.138	52.230	+0.092
Tall_weeds-129	386097.411	3295104.073	45.744	45.920	+0.176

Tall_weeds-130	394616.788	3287754.413	48.023	47.940	-0.083
TALL_WEEDS_2	387206.038	3324317.000	39.204	39.270	+0.066
TALL-WEEDS_5	383304.871	3313603.911	45.119	45.190	+0.071
TALL_WEED_6	395138.015	3307597.177	51.076	51.120	+0.044
TALL_WEED_7	396941.594	3299291.706	52.651	52.610	-0.041
BrushLands-120	379573.103	3329480.977	43.285	43.420	+0.135
BrushLands-121	388380.199	3328368.774	40.993	40.980	-0.013
BrushLands-122	398242.497	3333062.287	59.967	59.970	+0.003
BrushLands-123	394358.546	3318530.908	47.109	47.010	-0.099
BrushLands-124	376050.027	3320729.823	41.180	41.170	-0.010
BrushLands-125	386040.423	3319056.504	41.632	41.670	+0.038
BrushLands-127	385849.609	3306282.951	44.329	44.360	+0.031
BrushLands-130	399008.722	3287675.998	48.842	48.690	-0.152
BRUSH_2	387610.023	3323840.154	40.297	40.440	+0.143
BRUSH_6	395701.467	3305921.284	52.643	52.720	+0.077
BRUSH_6B	395722.018	3305926.747	52.795	52.710	-0.085
BRUSH_7	396944.828	3299341.982	52.607	52.660	+0.053
Forested-120	375996.300	3336087.374	43.116	43.160	+0.044
Forested-121	388492.953	3328995.119	42.022	42.020	-0.002
Forested-122	399235.218	3332621.006	62.386	62.280	-0.106
Forested-123	394787.302	3320128.478	48.448	48.460	+0.012
Forested-124	377923.648	3324991.265	44.666	44.850	+0.184
Forested-125	386689.172	3317600.259	42.462	42.560	+0.098
Forested-127	386692.039	3306856.792	44.787	44.860	+0.073
Forested-128	395923.985	3312508.638	49.881	49.940	+0.059
Forested-129	387067.235	3296645.427	45.857	45.860	+0.003
Forested-130	397030.185	3287298.871	44.439	44.540	+0.101
FOREST_2	388113.522	3323918.830	40.398	40.390	-0.008
FOREST_5	379457.452	3313578.590	47.133	47.130	-0.003
FOREST_6	395039.187	3307357.845	50.440	50.350	-0.090

Average dz	+0.029
Minimum dz	-0.50
Maximum dz	+0.60
Average magnitude	0.826
Root mean square	0.262
Std deviation	0.262